Cervical Spine Injury and Tracheal Intubation: A Never-Ending Conflict

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The incidence of cervical spine injuries following blunt trauma is 2% to 6 % (Table 1).[1–6] There are approximately 10,000 new cases of spinal injury each year in the United States, and the median age at injury is 25 years.[7] More males are injured than females (4:1 ratio), and the annual cost to society has been estimated at $5 billion.[7]

Table 1. Incidence of Cervical Spine Injuries

Population	Incidence (%)	Reference
Trauma, n=1,823	5.0	Baculis, 1987[1]
Trauma, n=9,044	4.3	Criswell, 1994[41]
Trauma, n=987	6.1	Wright, 1992[23]
Trauma, n=6,500	3.3	Domeier, 1996[4]
Trauma, n=7,518	2.2	Scannell, 1993[12]
Trauma, n=749	2.4	Cadoux, 1987[3]
Facial fractures, n=582	1.0	Beirne, 1995[2]
Head trauma, n=886	3.2	Nefield, 1988[5]
Head, face, and clavicular trauma, n=5,021	4.5	Williams, 1992[6]

Table 2. Symptoms and Signs of Cervical Spine Injury[7,13,24]

Neck pain, tenderness, deformity
Paresthesias, tingling
Diaphragmatic breathing
Hypoventilation
Neurogenic shock (loss of vasomotor tone and sympathetic innervation to heart)
Spinal shock (flaccidity and loss of reflexes)
Absent rectal tone
Sensory and motor abnormalities (inability to perceive pain below level of lesion may mask serious injury elsewhere)
Priapism

Table 3. Mechanism of Injury and Resultant Type of Fracture or Injury[7]

Flexion
Wedge fracture, flexion teardrop fracture, subluxation, bilateral facet dislocation, atlanto-occipital dislocation, anterior atlanto-axial dislocation, odontoid fracture with lateral displacement, clay shoveler's fracture, transverse process fracture
Flexion rotation
Unilateral facet dislocation, rotary atlanto-axial dislocation
Extension
Posterior neural arch fracture (C1), hangman's fracture (C2), posterior atlanto-axial dislocation, extension teardrop fracture, avulsion
Vertical compression (axial loading)
Burst fracture of vertebral body, Jefferson fracture (C1)

Diagnosis

Spinal cord injury is diagnosed based on mechanism of injury, symptoms, and signs (Tables 2 and 3). Mechanism of injury includes flexion, rotation, extension, axial loading, distraction, and lateral bending (Figs. 1 and 2). The majority of injuries occur as a result of motor vehicle collisions (MVCs). In one study of 133 patients with cervical spine injuries, 64% were caused by MVCs, 19% by falls, 7% by assault, 5% by diving, and 5% by sports.[8] In the study, 81% of injuries involved the subaxial segments C3–C7, and the remainder involved the occipito-atlantal and atlanto-axial segments.[8]

Clearing the Cervical Spine Before Intubation

No imaging modality is accurate 100% of the time.[9] Most studies have found that a three-view spine series, supplemented by thin-cut axial computed tomography (CT) images with sagittal reconstruction through suspicious areas or inadequately visualized areas, provides a false-negative rate of less than 0.1% if the studies are technically adequate and properly interpreted.[9] The recommendations by the Eastern Association for the Surgery of Trauma[9] are followed at the author's institution:

1. Trauma patients who are alert and awake and have no mental status changes, no neck pain, no distracting pain, and no neurologic deficits may be considered clinically to have a stable cervical spine.
2. All other trauma patients receive the following three cervical spine x-ray films: a) lateral view revealing the base of the occiput to the upper border of the first thoracic vertebrae, b) anteroposterior view revealing the spinous processes of the second cervical through the first thoracic vertebra, and c) an open mouth odontoid view revealing the lateral masses of the first cervical vertebra and entire odontoid process. Axial CT scans with sagittal reconstruction are obtained for any questionable level of injury or through the lower cervical spine if this area cannot be

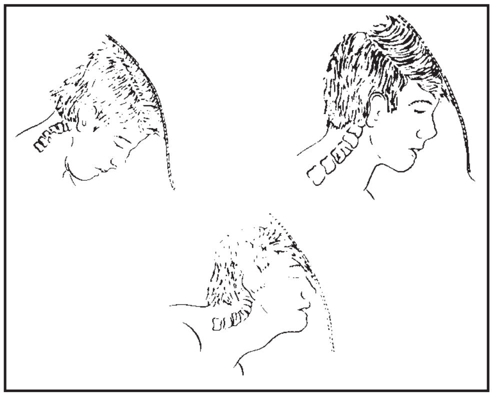

Figure 1.
The majority of cervical spine injuries occur as a result of motor vehicle collisions and falls. Flexion, flexion rotation, and extension can all cause cervical spine instability. (From McSwain NE. Mechanisms of injury in trauma. In McSwain NE, Kerstein MD, eds. The Evaluation and Management of Trauma. East Norwalk, CT, Appleton-Century-Crafts, 1987.)

Figure 2. Bilateral jumped facets, C3 on C4, as a result of a flexion injury incurred following a diving accident. The patient complained of tingling and numbness of his upper extremities but was otherwise neurologically intact. His trachea was intubated orally using flexible fiberoptic bronchoscopy and manual in-line axial stabilization. Sedation was achieved with droperidol and fentanyl. Local anesthesia was with transtracheal and bilateral superior laryngeal nerve blocks and oral topicalization (lidocaine).

visualized on plain radiographs. Before removing immobilization devices, all films are read by a physician with expertise in interpreting these studies.

3. Patients with neurologic deficit receive immediate subspecialty consultation.
4. A patient with an altered level of consciousness due to a traumatic brain injury or due to other causes considered likely to leave the patient unable to complain of neck pain or neurologic deficits for 24 or more hours after injury may be considered to have a stable cervical spine if adequate x-ray films (with CT supplementation as necessary) and thin-cut axial CT images through C1 and C2 are read as normal by an experienced physician.

Airway Management

The principles of Advanced Trauma Life Support (ATLS®) are followed.[10] Life-threatening injuries are attended to while minimizing any movement of the spinal column. New neurologic deficits occur 7.5 times more frequently with an unrecognized injury, and up to 10% of cervical-spine-injured patients will suffer a new neurologic deficit if not immobilized.[11] Therefore, the head and neck are immobilized during all airway maneuvers if there is any suspicion of injury. Supplemental oxygen is provided. Basic airway maneuvers to ensure oxygenation and ventilation are done prior to tracheal intubation. Indications for intubation include requirement for surgery and general anesthesia, respiratory distress, airway protection, shock, and tracheal toilet.

The relative risk of airway maneuvers in a patient with an unstable cervical spine is dependent on both direct and indirect factors. Direct factors include type of injury, anatomic location of injury, and severity of structural compromise. Indirect factors consist of hemodynamic instability (e.g., shock), degree of respiratory compromise, and presence of other injuries (e.g., head, maxillofacial, abdomen, aorta, pelvis). For example, the mortality rate among trauma patients with cervical fractures who required intubation was 37%, with most deaths related to associated injuries, particularly head injury.[12]

Overzealous chin-lift maneuvers, jaw thrust, and conventional laryngoscopy can all cause movement of the unprotected cervical spine.[13] Head extension is absolutely contraindicated in the patient with known or possible cervical spine instability. Similarly, inadequate airway anesthesia during awake intubation may cause vigorous coughing, retching, and vomiting when the endotracheal tube is manipulated into the pharynx and larynx, which in turn can cause significant patient movement. The vast majority of cervical motion during glottic visualization and intubation with a Macintosh blade is produced at the occipito-atlantal and atlanto-axial joints.[14] The subaxial cervical segments are displaced only minimally.[14]

Approaches to Tracheal Intubation

A variety of approaches and devices to secure the airway in patients with limited neck movement have been described, including blind nasotracheal intubation, flexible fiberoptic bronchoscpy (FOB), conventional laryngoscopy, use of a McCoy laryngoscope, rigid fiberoptic intubation (Bullard, WuScope), gum elastic bougie, lighted stylets, retrograde technique, and cricothyroidotomy (Table 4).[13,15–23] The goal is to establish tracheal intubation without causing further injury to the spinal cord.[24] In patients who are awake and cooperative without respiratory distress, the trachea may be intubated electively after completion of appropriate workup. Patients with head trauma and those who are unconscious or uncooperative often require rapid-sequence intubation (RSI) with manual in-line axial stabilization (MIAS).[25] Failed intubation usually necessitates a surgical airway (e.g., cricothyrotomy).

There are no clear guidelines for the optimal method to secure the airway in patients with cervical spine injuries, with the exception that the head and neck must be kept in a neutral position throughout the intubation procedure.[13,15] At the author's institution, head and neck movement and stabilization of the spine during oral intubation usually are prevented with MIAS (Fig. 3). Alternatively, a rigid cervical collar with tape and sandbags or surgical immobilization (tongs, halo-vest) is used (Fig. 4).

Table 4. Selected Retrospective Studies of Airway Management Techniques and Outcome in Patients with Cervical Spine Injuries Needing Intubation

Population and Reference	Techniques	New Neurologic Deficit
N=454; Meschino, 1992[19]	165 patients needed intubation (36%) Awake FOB, 76 Awake blind nasal, 53 Awake direct laryngoscopy, 36	11 patients total (2.4%) 7 non-intubated, 4 intubated. 2 before intubation, 2 several hours after after normal post-intubation exam
N=393; Criswell, 1994[41]	104 needed intubation RSI, 73 Blind nasal, 18 FOB, 11 Cricothyrotomy for failed intubation, 2	No new deficit (95% confidence interval 0–4%)
N=150; Suderman, 1991[18]	All needed intubation for surgical stabilization GA and direct laryngoscopy, 67 GA, other technique, 14 (e.g., FOB, lighted stylet, blind nasal) Awake FOB, 37 Awake direct laryngoscopy, 22 Awake lighted stylet, 8	2 patients (1.3%) 1 radiculopathy, resolved after 72 hr 1 quadraplegia, surgical wire passed through cord
N=60; Wright, 1992[23]	53 had unstable injuries Oral intubation, 26 Nasal intubation, 25 Cricothyrotomy, 2	1 patient (1.8%) after nasal intubation
N= 168; Scannell, 1993[12]	81 needed intubation, all with RSI	None; 4 had improvement in deficit after intubation

RSI, rapid-sequence intubation; GA, general anesthesia; FOB, fiberoptic bronchoscope

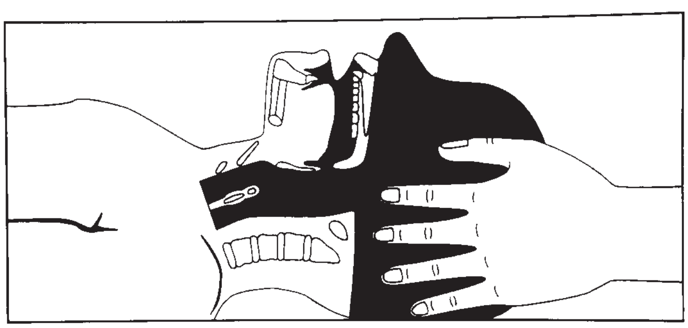

Figure 3. Manual in-line axial stabilization (MIAS) is applied by holding the sides of the neck and the mastoid processes and exerting downward pressure, thus preventing movement of the head and neck during intubation.

Stabilization of the cervical spine results in a higher incidence of difficulty with visualization of the vocal cords using conventional direct laryngoscopy.[26–28] This is because optimal alignment of the airway axes requires a certain amount of cervical segmental and rotational motion,[14] which is prevented by stabilization techniques. For example, Nolan et al[26] showed that MIAS of the cervical spine resulted in a 22% incidence of grade III views (vocal cords not seen but epiglottis visualized) and reduced the optimal view of the larynx in 45% of patients (Table 5).

Figure 4. The patient has suffered traumatic brain injury. He is lying on a long spine board and his neck is immobilized using a rigid collar, hard foam, and straps.

Nonurgent Cases

In nonurgent cases (e.g., cervical spine posterior fusion, patient in a halo vest or other traction device), awake flexible fiberoptic intubation is a fast, safe, and reliable technique with a very low failure rate, provided that the operator has all the equipment, training, and skills necessary to perform the technique.[29,30] Awake intubation allows evaluation of the patient's neurologic status after intubation or after positioning, before inducing general anesthesia. Sufficient airway anesthesia, conscious sedation (e.g., with midazolam, droperidol, fentanyl), an antisialagogue agent, and a topical vasoconstrictor if the nasal route is chosen are essential elements of awake

Table 5. Cervical Spine Immobilization and Grade View with Conventional Laryngoscopy During General Anesthesia and Complete Neuromuscular Blockade

Condition	Incidence of Grade III and IV Views* (%)	Reference
MIAS+	14	Hastings, 1994[27]
MIAS	22	Heath, 1994[28]
MIAS	39	Smith, 1999[36]
Rigid collar	26	Gabbott, 1996[45]
MIAS and cricoid pressure	22	Nolan, 1993[26]
MIAS and cricoid pressure	34	Laurent, 1996[46]
Rigid collar with tape and sandbags	66	Heath, 1994[28]

* Grade III view: only epiglottis visible, glottis cannot be seen[48]

* Grade IV view: only hard palate visualized, epiglottis and glottis cannot be seen[48]

+ MIAS, manual in-line axial stabilization

fiberoptic intubation. An antifog solution should also be used to ensure optimal illumination through the fiberscope. Two suction devices should be available: one for the fiberscope and another for the Yankauer. A silicone spray or other lubricant is recommended to ensure easy advancement of the tracheal tube over the fiberscope. The Ovassapian airway is particularly useful as a guide for flexible fiberoptic orotracheal intubation.

Rigid fiberoptic laryngoscopy with anatomically shaped blades (e.g., Bullard laryngoscope[31–33] and WuScope[34–36]) are also reliable techniques for visualization of the glottis and intubation of the trachea. Unlike conventional laryngoscopy, the Bullard and WuScope devices do not require head and neck movement to obtain a grade I view of the vocal cords. The WuScope is composed of a rigid blade portion and a flexible fiberscope (Fig. 5). The rigid blade is anatomically shaped to match the pharyngeal contour of the oral airway, thus allowing oral access to the glottis without tongue displacement or head extension. The tubular blade of the WuScope creates more viewing and intubating space and permits oral intubation in patients with limited mouth opening. At least 20 mm of mouth opening is, however, necessary to insert and manipulate the

Figure 5. The WuScope System consists of a tubular structured blade combined with a fiberscope. The blade contour permits access to the larynx without head extension. Note the tube passageway and the wide reversed 110-degree angle between the handle and the blade. The oxygen channel can also be used to inject local anesthetic.

rigid fiberoptic blades. The WuScope also has a separate channel for providing supplemental oxygen.

It has been shown that fiberoptic laryngoscopy using the WuScope is associated with easy glottic exposure and tracheal intubation in patients with cervical spine instability.[35] In a randomized study of fiberoptic WuScope versus conventional laryngoscopy in 87 patients with cervical spine immobilization, the WuScope was associated with Grade 1 views of the glottis in 98% of the patients, whereas 39% of patients in the conventional laryngoscopy group had Cormack grade III or IV views.[36] The WuScope can also be used for the placement of double-lumen endotracheal tubes (size 35 and 37 Fr). The two rigid blades combine to form a tubular exoskeleton, which protects the proximal tracheal cuff from tearing on the maxillary teeth as the double-lumen tube is advanced through the glottic opening. This technique is especially useful in patients with traumatic tears of the descending thoracic aorta who also may have cervical spine instability and require one-lung ventilation during surgical repair of the aorta.

The laryngeal mask airway (LMA) can provide a rapid clear airway in fasted patients with cervical spine injuries presenting for elective surgeries, thereby filling an important niche between the face mask and tracheal tube. The LMA also can be used as an aid to flexible fiberoptic intubation and as a bridging maneuver in the case of failed intubation. Advantages of the LMA include increased speed and ease of placement,[37] minimal hemodynamic effects, no increase in intraocular pressure, and a satisfactory airway in terms of oxygen saturation.[38]

The intubating LMA (iLMA) allows "blind" placement of an endotracheal tube of up to 8.0 mm internal diameter. However, the iLMA exerts greater pressures against the cervical vertebrae than other intubation techniques (e.g., flexible fiberoptic) and can produce posterior displacement of the cervical spine.[39] Moreover, the rigid iLMA tube compresses the posterior pharynx and has resulted in severe pharyngeal edema in patients undergoing anterior cervical spine fixation.[40]

Urgent and Emergent Cases

Conventional laryngoscopy is a faster means to secure the airway than most other techniques. Retrospectively, RSI with conventional laryngoscopy has not been shown to increase the risk of cervical spine injuries, as long as the head and neck are

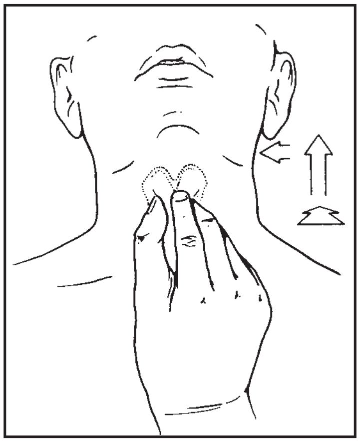

Figure 6. The view at laryngoscopy can often be improved by releasing cricoid pressure and applying **b**ackward pressure on the thyroid cartilage. Occasionally, the view can be further improved by adding **u**pward, and slightly **r**ightward **p**ressure on the thyroid cartilage, hence the acronym "BURP." The arrows indicate direction of pressure application. (Reproduced from Knill RL. Difficult laryngoscopy made easy with a "BURP". *Can J Anaesth* 1993; 40:279–82, with permission from the *Canadian Journal of Anaesthesia*.)

Figure 7. Heine Corazzelli-London flexible-tip version of the McCoy laryngoscope blade consists of a Macintosh blade with hinged tip and standard laryngoscope handle. The tip of the blade adjusts through 70 degrees by squeezing the lever.

Figure 8. The Heine Corazzelli-London flexible tip blade in the "activated" position. The blade tip lifts the epiglottis in a smooth, controlled motion, providing an improved view of the vocal cords, particularly in patients with cervical spine immobilization.

kept in a neutral position throughout the intubation procedure.[41] With RSI, it is advisable to remove the rigid cervical collar after applying MIAS. This is because the collar restricts mouth opening[28] and impedes the performance of cricoid pressure or external laryngeal manipulation. Anesthesia may be induced with thiopental, etomidate, ketamine, or propofol.[42] Induction agents may need to be given in reduced dosages to prevent hypotension and myocardial depression. Neuromuscular relaxants such as succinylcholine, rocuronium, and rapacuronium can be used.[42] Proliferation of extrajunctional acetylcholine receptors requires 24 to 48 hours after denervation injury.[25] Thus, succinylcholine-induced hyperkalemia is unlikely to occur in the acute setting.[25]

When using conventional laryngoscopy, the operator must be prepared for a higher incidence of grade III laryngeal views. External laryngeal manipulation or backward pressure on the thyroid cartilage applied by the operator's right hand often improves the view at laryngoscopy (Fig. 6).[44,45] In the author's experience, the simple maneuver of having the assistant ease up or release previously applied cricoid pressure during RSI (under direct laryngoscope vision) may alleviate airway distortion and permit rapid insertion of the tube through the vocal cords. The benefit of rapidly inserting the tracheal tube and inflating the cuff outweighs the potential risk of aspiration during the brief time that the cricoid pressure is not being applied.

The McCoy Corazelli London or Heine CL flex-tip laryngoscope blade has a hinged blade tip that is controlled by a lever attached to the blade (Figs. 7 and 8). This new laryngoscope blade, which attaches to a standard laryngoscope handle, allows the epiglottis to be elevated without requiring excessive lifting force and significantly improves the view at laryngoscopy in patients with cervical spine immobilization.[45–47] Use of the McCoy laryngoscope is invaluable in the author's practice for improving the laryngeal view and facilitating intubation in adult patients with difficult airway anatomy. Of particular note is the very short learning curve for using this blade. In the author's experience, any anesthesia provider who is comfortable with direct laryngoscopy using a Macintosh blade can become accomplished with this blade after only one or two attempts.

The gum elastic bougie (Figs. 9 and 10) is used to facilitate tracheal intubation in patients with cervical spine immobilization whenever a grade III view is encountered.[26] While performing direct laryngscopy and maintaining adequate laryngoscopic force to keep the epiglottis in full view, the bougie is introduced by the operator and gently advanced anteriorly under the epiglottis and into the trachea. With the operator still maintaining laryngoscopic force, a second operator then inserts the endotracheal tube over the bougie. Occasionally, the bougie may need to be rotated 90° for the tube to pass. It is relatively

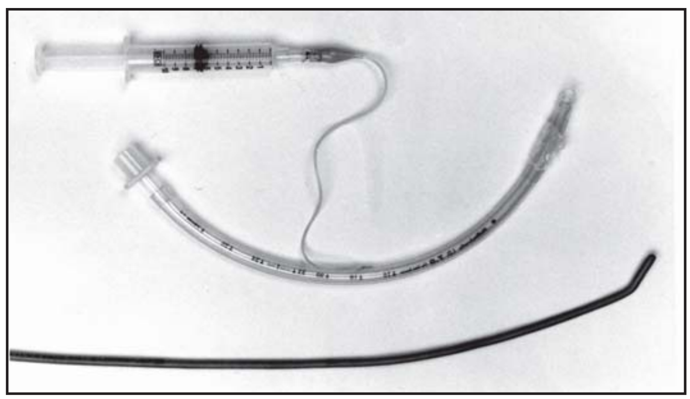

Figure 9. The gum elastic bougie is a 15 FR tracheal tube introducer fabricated from a braided polyester base with a resin coating to provide both stiffness and flexibility at body temperature. The bougie has a length of 60 cm and an external diameter of 5 mm and can accommodate endotracheal tubes with an inner diameter ≥ 6 mm.

Figure 10. Closeup of the tip of the gum elastic bougie. The smooth angled tip is designed to give directional control during difficult oral intubation when the laryngeal inlet cannot be visualized completely.

easy to insert a bougie through the glottic opening when only the epiglottis (grade III view) or posterior aspect of the glottis (grade II view) can be visualized. Tracheal placement is then confirmed using end-tidal CO_2.

Depending on skill, experience, and other factors, urgent and emergency tracheal intubation also can be performed using a variety of techniques, including, but not limited to, rigid fiberoptic laryngoscopy (e.g., Bullard, WuScope), FOB, and lighted stylets.

Summary

Major trauma is associated with a 2% to 6% risk of cervical spine injury. Motor vehicle collisions account for the majority of these injuries. No imaging modality is accurate 100% of the time, although most injuries can be detected with a three-view spine series and CT supplementation. Manual in-line axial stabilization is an effective technique to prevent cervical spine movement during intubation but may result in an increased incidence of difficulty with vocal cord exposure using conventional laryngoscopy. Moreover, rigid cervical collars restrict mouth opening and further decrease the ability to see the laryngeal inlet using direct laryngoscopy.

There are no prospective studies documenting that any intubation technique is dangerous provided that immobilization precautions are maintained. Awake intubation techniques permit neurologic evaluation after intubation. Intubation after induction of general anesthesia and neuromuscular blockade provides excellent intubating conditions, especially in patients who are not cooperative or cannot be sedated adequately. The optimal method of intubation ultimately depends on the patient's condition, degree of cooperation, urgency of situation, and skill of the traumatologist.

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